Eur J Clin Chem Clin Biochem
1995; 33:919–925

Medicolegal Alcohol Determination: Variability of the Blood- to Breath-Alcohol Ratio and Its Effect on Reported Breath-Alcohol Concentrations

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(Received March 13/July 7, 1995)

Summary: There is substantial agreement among scientists that the variability of a person's blood- to breath-alcohol ratio contributes significantly to the experimental error in results from breath-alcohol analysis. Some have argued that the need to correct for this source of error can be eliminated by reporting breath test results in units of breath-alcohol concentration rather than blood-alcohol concentration. A simple mathematical proof is presented to demonstrate that this is not the case. Moreover, the scientific and legal flaws of this argument are discussed, and recommendations are offered for dealing with the problems that have developed from adoption of this view.

Introduction

In 1990, *Labianca* (1) detailed the chemical basis of the operation of the Breathalyzer. That instrument – and other breath-alcohol analyzers currently used in law enforcement – employs a *constant* blood- to breath-alcohol ratio (hereinafter termed, "blood/breath ratio") to convert the breath-alcohol concentration of a Driving-While-Intoxicated (DWI) suspect into his/her corresponding blood-alcohol concentration. The problem with this type of conversion, as emphasized by *Labianca* (1) and others, including *Simpson* (2, 3), is that it fails to take into account substantial inter- and intra-individual variations in blood/breath ratios.

For many years, scientists have been acutely aware of the uncertainty associated with data generated from the uniform application of a constant blood/breath ratio to breath test subjects. In this regard, *Mason* and *Dubowski* (4, 5) recommended in the 1970s that breath- to blood-alcohol concentration conversions be abandoned, and that the offense of driving-while-intoxicated be statutorily defined in terms of specified limits of breath- rather than blood-alcohol concentration in jurisdictions employing breath-alcohol analysis. That recommendation – which was subsequently endorsed by others, including *Jones* (6) in 1978 – was further emphasized by *Dubowski* in 1983 (7), when he stressed that the proposal "simply recognizes the wide variability of the physiological blood/breath ratio." The apparent simplicity and problem-free nature of this recommendation has led to its adoption by the National Highway Traffic Safety Administration (NHTSA) of the US Department of Transportation, and has prompted a number of states in the USA during the last decade to adopt the recommendation as well and enact *direct* breath-alcohol statutes. Other states currently considering the recommendation may also follow suit.

The enactment of *direct* breath-alcohol statutes, however, has not eliminated the need to correct for the experimental error stemming from the conversion of breath- into blood-alcohol concentration via multiplication of the former by a constant blood/breath ratio. In fact, the enactment of such statutes has, in at least one case, resulted in the *legislation* of incorrect science.

Using an elementary mathematical analysis, this article focuses on the *scientific* reasons why direct breath stat-

utes are not acceptable and also proposes the means by which the problems created by such statutes can be remedied.

Scientific and Legal Overview

The first demonstration of the incorrect science embodied in a particular breath-alcohol concentration statute, namely the California statute, was documented by *Simpson* (8). He showed that, implicit in the statute, is an equation that incorrectly describes the relationship between blood- and breath-alcohol concentration in a human subject. The California statute criminalizes driving with 0.08% or more by weight of alcohol in *blood* (0.8 g/l blood), and permits 0.08% by weight to be established by *either* 0.08 g/100 ml blood (blood-alcohol concentration) – that is, 0.8 g/l blood – *or* 0.08 g/210 l breath (breath-alcohol concentration), which is 0.00038 g/l breath. If, however, 0.08 g/100 ml blood (0.8 g/l blood) = 0.08% by weight, and 0.08 g/210 l breath (0.00038 g/l breath) = 0.08% by weight, then it necessarily follows that 0.08 g/100 ml blood (0.8 g/l blood) = 0.08 g/210 l breath (0.00038 g/l breath), and that blood-alcohol concentration equals breath-alcohol concentration. The California legislature thus put into law the relationship, blood-alcohol concentration (BAC) equals breath-alcohol concentration (BrAC), which is incorrect. In fact, BAC $\propto$ BrAC, so that, at a given temperature, the correct relationship describing the partitioning of alcohol between a test subject's blood and breath is given by equation 1.

$$BAC_{Act.} = R \times BrAC_{Meas.} \qquad \text{(Eq. 1)}$$

In this equation, $BAC_{Act.}$ is the *actual* blood-alcohol concentration that would correspond to the result of a direct analysis of the subject's blood if he/she opted for such an analysis; $BrAC_{Meas.}$ is the *measured* breath-alcohol concentration that would characterize the subject if he/she opted for a breath test instead; and R is the subject's blood/breath ratio *at the time* of the breath test.

In contrast to California are those jurisdictions that have enacted statutes defining driving-while-intoxicated in terms of blood-alcohol concentration and a coexisting breath-alcohol concentration, the former serving as the basis for the evaluation of driving-while-intoxicated suspects unable, or unwilling, to undergo a breath test. While these statutes do not contain the incorrect relationship, blood-alcohol concentration equals breath-alcohol concentration, they embody other scientific and legal flaws. These stem from the fact that, a specific breath-alcohol concentration limit is probative *if and only if* there is sufficient ethanol in the *blood* to produce the state of intoxication defined by the breath-alcohol concentration limit. That condition *must* be met, for it is possible to obtain a breath-alcohol concentration result equal to, or in excess of, a statutory limit when there is little or no ethanol in the blood. This can occur, for example, if a test subject's breath is contaminated by mouth alcohol (9, 10) and/or by a compound capable of producing a false ethanol reading on a breath analyzer (11, 12). Direct breath-alcohol concentration statutes, therefore, merely *assume* that, in *all* cases, there is *sufficient* ethanol in the blood to produce breath-alcohol concentration results indicative of driving-while-intoxicated. Thus, these statutes, in conjunction with the direct blood-alcohol concentration statutes that they must necessarily coexist with, "lock into place" equation 2, where k, in contrast to R, is the *assumed* blood/breath ratio for *all* test subjects.

$$BAC_{Act.} = k \times BrAC_{Meas.} \qquad \text{(Eq. 2)}$$

Scientific and Legal Flaws

In the context of specific statutory limits in the USA, $BAC_{Act.}$ and $BrAC_{Meas.}$ are typically defined in terms of the *same* weight of alcohol in two different phases – for example, *0.10 g*/100 ml blood (1.0 g/l blood, liquid phase) and *0.10 g*/210 l breath (0.00048 g/l breath, gas phase). The latter concentration is equal to 48 µg/100 ml breath, which reflects the concentration unit used in some European jurisdictions (13, 14)[1]). Under these circumstances, k must equal 2100. A *constant* blood/breath ratio, therefore, is applied to all drivers and is used by a legislature to set a breath-alcohol concentration limit when equation 2, with k = 2100, is solved for $BrAC_{Meas.}$, as expressed by equation 3.

$$BAC_{Act.} \times \frac{1}{2100} = BrAC_{Meas.} \qquad \text{(Eq. 3)}$$

A statute that establishes a specific breath-alcohol concentration limit in this way does not solve the problem of blood/breath ratio variability that *Dubowski* (4, 5, 7) and *Jones* (6) sought to eliminate. It simply ignores that variability, which is the essence of its scientific flaw. Moreover, since the statute operates under the assumption that any driving-while-intoxicated suspect who undergoes a breath test is characterized by a 2100 : 1 blood/breath ratio, it is also legally flawed; if the statute does "greatly enhance the investigation and disposition of [driving-while-intoxicated] charges", as claimed by *Dubowski* (7), it does so by inappropriately relieving the

[1]) International scientific bodies, however, recommend use of SI units: 0.8 g/l = 17.4 mmol/l; conversion factor: g/l × 21.71 = mmol/l.

prosecution of its burden to establish that the defendant had a blood/breath ratio of 2100 : 1 or more at the time of the breath test. That is, this assumption precisely fits the definition of a *presumption*, which is a legal *inference* of the existence or truth of a fact for which there is not direct evidence, but which is determined by inference from the existence of a *foundational* fact (15). Thus, for breath-alcohol concentration statutes, the foundational fact is the existing blood-alcohol concentration limit used for blood tests, and from this, a breath-alcohol concentration limit is inferred by assuming the existence of a constant blood/breath ratio, namely 2100 : 1, to relate the two via equation 3. A critical point, however, is that, when used to construct statutes or to establish facts in criminal cases, a presumption must be rebuttable. Because a presumed fact may not be correct in a given case, due process guarantees of the 14th Amendment of the US Constitution require that the defendant be allowed to rebut that presumption. That certainly would be the situation if, for example, the presumption of a 2100 : 1 blood/breath ratio were to be applied to a driver characterized by a 1600 : 1 blood/breath ratio instead of a 2100 : 1 ratio at the time of his/her breath test. Assuming no other sources of error, this would result in an overestimate of actual blood-alcohol concentration by 31%, which is equivalent to stating that actual blood-alcohol concentration would be about 24% less than the blood-alcohol concentration derived from breath-alcohol analysis.

How can this situation be remedied, given that a breath analyzer cannot adjust for the variability of each test subject's blood/breath ratio and, therefore, cannot function on the basis of equation 1? The answer is provided below within the context of a straightforward mathematical analysis.

The Role of the Multiplication Property of Equality

Consider that, for many years, the analytical method used by law enforcement agencies in the USA and elsewhere to determine a driving-while-intoxicated suspect's blood-alcohol concentration has involved the determination of the suspect's $BrAC_{Meas.}$ (g/100 ml breath or g/l breath) and its conversion into the corresponding *estimated* blood-alcohol concentration ($BAC_{Est.}$) (g/100 ml blood or g/l blood) via equation 4.

$$BAC_{Est.} = 2100 \times BrAC_{Meas.} \qquad \text{(Eq. 4)}$$

This equation is clearly a specific application of equation 2 and, in fact, dictates that $BAC_{Est.} = BAC_{Act.}$ when the 2100 : 1 ratio is the *actual* blood/breath ratio of the suspect at the time of his/her breath test, and no other sources of error exist. Furthermore, it should be noted that, for blood-alcohol concentration statutes based on breath testing and, therefore, relying on equation 4, the *foundational* fact is $BrAC_{Meas.}$, and the existence of a 2100 : 1 blood/breath ratio is assumed to obtain the *presumed* fact, $BAC_{Est.}$.

Obviously, when the driving-while-intoxicated suspect's ratio differs from 2100 : 1, equation 4 becomes an incorrect indicator of his/her actual blood-alcohol concentration and must be transformed into the equivalent of equation 1 to correct for the error arising from the suspect's blood/breath ratio. Given the construction of current blood-alcohol concentration statutes involving breath testing and consistent with equation 4, a practical way to effect this transformation is to multiply both sides of equation 4 by the dimensionless correction factor, R/2100, to give equation 5.

$$\underbrace{\frac{R}{2100} \times BAC_{Est.}}_{BAC_{Act.}} = 2100 \times \underbrace{BrAC_{Meas.} \times \frac{R}{2100}}_{BrAC_{Cor.}} \qquad \text{(Eq. 5)}$$

This operation is in accord with the application of the elementary mathematical axiom, the *multiplication property of equality* (16), to equation 4. This procedure, which has been described elsewhere (17), necessarily dictates that both sides of equation 4 *must* be multiplied by the *same* non-zero quantity if the equality reflected by the equation is to be retained and an equivalent equation is to be produced. Equation 5, clearly the equivalent of equation 1, relates $BAC_{Act.}$ to the *corrected* breath-alcohol concentration ($BrAC_{Cor.}$).

Since the variability of the blood/breath ratio generates errors in values of $BAC_{Est.}$ provided by equation 4, a point explicitly acknowledged by *Dubowski* (4, 5, 7) and *Jones* (6, 18), equation 5 provides an acceptable method of dealing with those errors, which can be substantial and, therefore, detrimental to defendants in driving-while-intoxicated cases (2, 3, 19, 20). While it is possible to determine R for each individual at the time of a breath test, it is not practical. Consequently, to make corrections in $BAC_{Est.}$ according to equation 5, the only approach at present is to use population data for blood/breath ratios corresponding to appropriate confidence limits. As recently stated by *Rainey* (21), who relied on lognormal-transformed data, mean $\pm$ 2.58 SD (99% confidence limits) is the appropriate confidence interval for conversions of body-fluid alcohol concentrations when a standard of "beyond a reasonable doubt" is required. The same correction can be applied to values of $BAC_{Est.}$ when multiplying them by R/2100 by setting R equal to "mean − 2.58 SD". This "mean" would correspond to the lognormal-transformed mean blood/breath

ratio derived from population data associated either with the absorptive or postabsorptive states of alcohol consumption (2, 3, 19–20).

For some reason, *Dubowski* and *Jones* chose not to endorse this use of corrected blood-alcohol concentration results for breath resting. Instead they claimed that reporting breath test results in terms of breath-alcohol concentration would eliminate use of the 2100 : 1 ratio and, therefore, the necessity for correction. In other words, by claiming there is no need to correct breath-alcohol concentration results, *Dubowski* and *Jones* concluded that, $BrAC_{Meas.} = BrAC_{Cor.}$. The latter equation, however, can only be derived by violating the multiplication property of equality. That is, for example, when both sides of equation 5 are multiplied by the reciprocal of the 2100 : 1 ratio, in accord with the multiplication property of equality, equation 6 is obtained, demonstrating unequivocally that $BrAC_{Meas.} \neq BrAC_{Cor.}$, except as noted below.

$$BAC_{Act.} \times \frac{1}{2100} = BrAC_{Meas.} \times \frac{R}{2100} = BrAC_{Cor.} \quad \text{(Eq. 6)}$$

Notice that equation 6 requires that $BrAC_{Meas.}$ be multiplied by R/2100 to yield $BrAC_{Cor.}$, just as a driving-while-intoxicated defendant is permitted to multiply $BAC_{Est.}$ by R/2100 to obtain $BAC_{Act.}$ in order to correct breath test results reported in terms of blood-alcohol concentration.[2]) Notice too the *sole* condition under which equation 6 becomes identical to equation 3 and is, therefore, consistent with "locked-into-place" equation 2: *only* when a subject's blood/breath ratio at the time of his/her breath test is 2100 : 1. The difficulties created by *Dubowski* and *Jones*' claim, therefore, arise from an elementary error, namely inappropriate use of equation 3. While this equation correctly describes the relationship between $BAC_{Act.}$ and $BrAC_{Meas.}$ in the special case where k = 2100, it has been, and still is being used as though it is correct for all cases in which a breath test is employed.

An Illustrative Case History

The significance of equation 6 can be further gleaned from its application to an actual case described by *Simpson* (8). The case involved a severely asthmatic defendant charged with driving-while intoxicated in California prior to that state's adoption of its present breath-alcohol concentration statute. The charge was based on a $BAC_{Est.}$ of 0.09 g/100 ml blood (0.9 g/l blood). (Recall that the statutory blood-alcohol concentration limit in California is 0.08 g/100 ml blood [0.8 g/l blood]). The defendant presented evidence at his trial – stemming from controlled sampling of blood- and breath-alcohol conducted at some point in time after he was charged – that showed a post-peak blood/breath ratio of 1233 : 1 and that resulted in an eventual dismissal of the case. He argued that this blood/breath ratio was substantially below 2100 : 1 at the time of his breath test, and that his $BAC_{Act.}$ ($BAC_{Est.} \times R/2100$, according to equation 5) was 0.05 g/100 ml blood (0.5 g/l blood, obtained from, 0.9 g/l blood × 1233/2100). Had this defendant been charged under California's current direct breath statute – which, as noted above, criminalizes breath-alcohol concentration results at, or in excess of, 0.08 g/210 l breath (0.00038 g/l breath) – his $BrAC_{Meas.}$ would have been 0.09 g/210 l breath (0.00043 g/l breath). He would not have been permitted to use equation 6 to convert this result into a $BrAC_{Cor.}$ of 0.05 g/210 l breath (0.00024 g/l breath) because, under the current statute, evidence of a defendant's blood/breath ratio has been ruled irrelevant.

The data and circumstances of this case are certainly not unique. *J. C. Russell & R. L. Jones* (22), for example, in their study of subjects with chronic obstructive pulmonary disease – which includes conditions such as emphysema and asthma (23) – concluded that, "quantitative measurement [involving breath-alcohol analysis] must be approached with caution" when test subjects lack effective pulmonary function. In addition, *Giguiere & Simpson* (20) demonstrated that a blood/breath ratio of 1233 : 1, which was exhibited by the asthmatic defendant in the above case, could also characterize an otherwise healthy subject absorbing alcohol into the circulation of the time of a breath test and faced with the same charge as that defendant. In this regard, even *Mason & Dubowski* (4) said, "... when blood and breath tests are available to a subject, the breath test can be discriminatory in yielding a higher result than a blood test during absorption." So for this "healthy" subject, $BAC_{Act.}$ would be 0.05 g/100 ml blood (0.5 g/l blood) if he were to undergo a direct blood-alcohol analysis at the time his blood/breath ratio was 1233 : 1, and he would not be classified driving-while-intoxicated in California. If, on the other hand, he were to submit to a breath test, the result, as expected, would be 0.09 g/210 l breath (0.00043 g/l breath), and he would be classified driving-while-intoxicated. Guilt or innocence, therefore, would depend on which test was used to evaluate the subject; while this can be true even when breath test results are reported in terms of blood-alcohol concentration, at least there is an opportunity to challenge the presumption of a 2100 : 1 blood/breath ratio under those circumstances. Both of these examples reinforce the argument offered previously: enactment of direct breath statutes does not solve the problem of blood/breath ratio variability; instead, the problem is simply ignored.

[2] One of the reasons for adopting a recommendation that violates multiplication property of equality is the following: by expressing breath-alcohol concentration results in the USA in units of g/210 l breath, manufacturers can supply identical breath-alcohol analyzers nationwide. This eliminates the need for different models in "breath-alcohol concentration and blood-alcohol concentration jurisdictions" as long as the concentration units do not have to be recorded on the evidence card, i. e., as long as only the numerical value is reported. However, the fact that the same breath-alcohol analyzers calibrated in the same way can now be used in both "breath-alcohol concentration and blood-alcohol concentration jurisdictions" is a clue that nothing is really changed by enacting direct breath-alcohol concentration statutes. Is there really any substantive difference between a legislature requiring that breath-alcohol analyzers use 2100 to convert measured breath-alcohol concentration results to blood-alcohol concentrations, and a legislature that uses 2100 to convert an existing blood-alcohol concentration limit to a breath-alcohol concentration limit? In the former case, the equation, BrAC × 2100 = BAC, is used to convert a breath test result into a corresponding blood-alcohol concentration result; in the latter case, the *same* equation – in the form, BrAC = BAC/2100 – is used to set a statutory limit for breath-alcohol concentration, and measured breath-alcohol concentrations are compared to this new limit. The two approaches are, in fact, equivalent, as shown by use of the same equation, but the latter approach creates legal difficulties that appear to violate due process guarantees in the US Constitution.

Constitutional Considerations and Corrections for Blood/Breath Ratio Variability

From a legal standpoint, a legislature's use of equation 3 to set a statutory breath-alcohol concentration limit, as described above, is tantamount to instructing jurors that they are *required* to presume or infer that the defendant's blood/breath ratio was 2100 : 1, or greater, when he/she was tested, and that the defendant is not permitted to rebut this presumption in any way. Obviously, in a situation such as this, the asthmatic defendant in the case described above would have been unjustly convicted of driving-while-intoxicated. It is thus important that a defendant be permitted to rebut the assumption that his/her blood/breath ratio was 2100 : 1, or greater, at the time of the breath test. Moreover, as noted previously, the use of such an irrebuttable presumption to establish an element of a criminal offense, or to criminalize certain behavior by statute, is not permitted under the due process clause of the 14th Amendment of the US Constitution; consequently, direct breath statutes, as currently formulated, appear to be unconstitutional.

Under broad police powers (15), legislatures are probably permitted to satisfy the "rational basis requirement" for enacting direct breath statutes by determining that it is dangerous for people to drive with a certain minimum breath-alcohol concentration, assuming the availability of sufficient evidence to establish that minimum. Such evidence, however, does not exist at this time. As pointed out by *Simpson* (3, 24), there is at present no established method or procedure by which alcohol-induced impairment of driving skills can be reliably related to breath-alcohol concentration; the complexity of this task is such that there is not even agreement about what test or combination of tests might be appropriate. Furthermore, breath analysis experiments that have involved impairment of some of these skills have almost always employed only postabsorptive subjects. Consequently, little is known about the relationship between breath-alcohol concentration and impairment for the period of time involving the absorption and/or equilibration-distribution of alcohol, a period of time that is often significant in forensic applications of breath-alcohol analysis. Because of this lack of appropriate experimental results involving impairment, the *only* means available to legislatures at present to set a statutory breath-alcohol concentration limit is to base it on an existing blood-alcohol concentration limit, and that is what has been done in a number of cases. There is still a need, however, to allow for the error in breath test results due to variability of the blood/breath ratio, and this could be accomplished by means of equation 6. This would be a scientifically and legally sound alternative to the position taken by *Mason & Dubowski* (4), namely that a breath-alcohol concentration corresponding to a statutorily defined blood-alcohol concentration limit "may be directly calculated by using this [2100 : 1] ratio." But implementing such a "calculation" would depend on equation 3 and would, therefore, preclude the use of equation 6 to correct for the analytical error arising from the variability of the blood/breath ratio. Similarly, *Jones* has also acknowledged that specific blood/breath ratios have been used to set statutory breath-alcohol concentration limits both in the USA and elsewhere (18, 25), a procedure restricted, once again, to the use of equation 3, or a modification of that equation when a ratio other than 2100 : 1 was involved. (With regard to the latter point, a blood/breath ratio of 2000 : 1 is used in Austria, and 2300 : 1 in Great Britain and The Netherlands [18].)

It should be noted that the matter of correcting raw data obtained from breath-alcohol analyses, in a manner conforming to the constitutional guarantees of defendants in criminal proceedings, has not been entirely ignored by *Dubowski* and *Jones*. *Dubowski* (26), for example, indicated a subtraction factor of 0.025 g/100 ml blood (0.25 g/l blood), for 99.7% confidence limits at a $BAC_{Est.}$ of 0.10 g/100 ml blood (1.0 g/l blood). This adjustment represents a 25% correction factor for the variability in the blood/breath ratio, based on postabsorptive data obtained by *Dubowski* (27). If applied to a postabsorptive $BrAC_{Meas.}$ of 0.10 g/210 l breath (0.00048 g/l breath), this correction would be equivalent to 0.025 g/210 l breath (0.00012 g/l breath). *Dubowski* (26) stated, however, that such a correction would be unnecessary if a direct breath-alcohol concentration statute were to be enacted.

Dubowski (o. c. (26), 18-57; 18-68) also indicated, apparently on the basis of work reported in 1981 (28), that a subtraction factor of 0.03 g/210 l breath (0.00014 g/l breath) at a $BrAC_{Meas.}$ of 0.10 g/210 l breath (0.00048 g/l breath) be used to correct for variability in Breathalyzer 900A test results compared to corrresponding analyses by gas chromatography. At a $BAC_{Est.}$ of 0.10 g/100 ml blood (1.0 g/l blood), the subtraction factor would be 0.03 g/100 ml blood (0.3 g/l blood). In this case, however, *Dubowski* maintained that, unless other means were adopted, it *would* be necessary to take this subtraction factor into account for every breath test result in order to correct for error from this source.

Jones (25), on the other hand, suggested that, for "99.9% confidence [which] gives the defendant an acceptable margin of safety ... at a critical legal limit," a factor of 0.015 g/210 l breath (0.00007 g/l breath) might be subtracted "from the mean of a duplicate determination on separate breaths." At a statutory

breath-alcohol concentration limit of 0.10 g/210 l breath (0.00048 g/l breath), *Jones'* suggested adjustment would be equivalent to a 15% correction factor. From work published earlier by *Jones* (29), however, a subtraction factor of 26% would apply for 95% confidence limits, and about 40% for 99.7% confidence limits, at a mean $BAC_{Est.}$ of 0.05 g/100 ml blood (0.5 g/l blood). This work involved 506 blood/breath pairs, breath-alcohol concentration having been measured with a Breathalyzer 900.

In the final analysis, corrections such as those described above reinforce the argument that, whenever breath-alcohol testing is used to evaluate driving-while-intoxicated suspects, the variability of the blood/breath ratio cannot be ignored. This is consistent with the view that legislatures are not permitted to employ an irrebuttable presumption – that is, effectively mandating an assumption that *any* driver who has ingested alcohol has a blood/breath ratio of 2100 : 1 – to construct a direct breath-alcohol statute of the type endorsed by *Dubowski* and *Jones*, and, consequently, dependent on equation 3. If such a device is employed, the resulting statute appears to violate the due process standard, even if the rational basis criterion is satisfied. Clearly, any suspect having an abnormally high breath-alcohol concentration for the amount of alcohol consumed, such as the asthmatic described earlier, would have his/her due process rights violated.

Conclusion

The flawed nature of direct breath-alcohol statutes can be rectified via a return to the statute construction used previously, whereby use of the 2100 : 1 ratio as applied to an individual is rebuttable in a court of law. That type of construction, which is still in place in many jurisdictions in the USA, would be consistent with equation 6. In fact, statutes so constructed would be acceptable from both scientific and legal viewpoints and would be appropriate replacements for current direct breath statutes, which are acceptable from neither viewpoint.

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